REMOTE CONTROL AUTOMATIC APPLIANCE ACTIVATION

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to wireless remote control of appliances such as, for example, garage door openers.

2. Background Art

Home appliances, such as garage door openers, security gates, home alarms, lighting, and the like, may conveniently be operated from a remote control. Typically, the remote control is purchased together with the appliance. The remote control transmits a radio frequency activation signal which is recognized by a receiver associated with the appliance. Aftermarket remote controls are gaining in popularity as such devices can offer functionality different from the original equipment remote control. Such functionality includes decreased size, multiple appliance interoperability, increased performance, and the like. Aftermarket controllers are also purchased to replace lost or damaged controllers or to simply provide another remote control for accessing the appliance.

An example application for aftermarket remote controls are remote garage door openers integrated into an automotive vehicle. These integrated remote controls provide customer convenience, appliance interoperability, increased safety, and enhanced vehicle value. Present in-vehicle integrated remote controls provide a "universal" or programmable garage door opener which learns characteristics of an existing transmitter by receiving an activation signal from the transmitter. Then, when prompted by a user, the programmable garage door opener generates an activation signal having the same characteristics. One problem with such devices is the difficulty experienced by users attempting to program the garage door opener. Another problem occurs if the user has lost all existing transmitters.

What is needed is a universal remote controller that is easier to program. This remote controller should be easily integrated into an automotive vehicle using simple electronic circuits.

SUMMARY OF THE INVENTION

The present invention provides a universal remote control that automatically learns characteristics necessary to generate an appliance activation signal.

A method for remotely activating an appliance is provided. The appliance responds to an activation signal conforming to one of a plurality of radio frequency activation schemes. A sensor is positioned proximate to the appliance. A sequence of different activation signals is automatically transmitted. Each activation signal conforms to one of the radio frequency activation schemes. At least one signal is received from the sensor indicating appliance activation. A determination as to which of the radio frequency activation schemes resulted in transmitting an activation signal that activated the appliance is made based on the received sensor signal. Data representing the determined activation scheme is associated with an activation input for a programmable remote control transmitter.

In an embodiment of the present invention, at least one of the radio frequency activation schemes is a fixed code scheme. The sequence of activation signals includes an activation signal having each possible fixed code value.

In another embodiment of the present invention, the sequence of activation signals transmits each rolling code activation signal before any fixed code activation signals.

In still another embodiment of the present invention, appliance activation is indicated by receiving a radio frequency signal from a remote sensor.

In yet another embodiment of the present invention, the programmable remote control transmitter is installed in a motor vehicle. The sensor signal indicating appliance activation is received from a vehicle-mounted sensor.

In a further embodiment of the present invention, the sensor generates a first signal and a second signal. The second signal confirms appliance activation by one of the radio frequency activation schemes. This may be accomplished by rapidly transmitting the sequence of activation signals prior to receiving the first sensor signal and slowly transmitting at least a portion of the rapidly transmitted sequence prior to receiving the second signal.

In yet a further embodiment of the present invention, at least a portion of the sequence of activation signals has an order established by priority of radio frequency activation schemes. This reduces an average time for receiving the sensor signal indicating activation.

Appliance activation may be detected by one or more of a variety of parameters including sensing motion of a mechanical barrier, sensing position of a mechanical barrier, sensing light emitted by the appliance, sensing vibration emitted by the appliance, sensing current drawn by the appliance, and the like.

A system for operating a remotely controlled appliance is also provided. The system includes a sensor for generating a sensor signal in response to the appliance. A transmitter sends radio frequency activation signals. Control logic causes the transmission of a sequence of different activation signals, each based on one of a plurality of activation schemes. In response to receiving a signal from the sensor, the control logic stores data into memory indicating which activation scheme activated the appliance.

A programmable appliance remote control is also provided. A controller operates in a learn mode and an operate mode. In learn mode, the controller generates transmitter control signals for transmitting each of a sequence of different activation signals. Each activation signal is based on one of a plurality

of activation schemes. The controller stores data representing one of the activation schemes based on receiving a sensor signal. In operate mode, the controller generates transmitter control signals based on the stored data in response to receiving an activation input signal. One or more of the controller, transmitter, sensor and user interface may be built into an automotive vehicle.

The above features, and other features and advantages of the present invention are readily apparent from the following detailed descriptions thereof when taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a schematic diagram illustrating appliance control according to an embodiment of the present invention;

FIGURE 2 is a schematic diagram illustrating activation signal characteristics according to an embodiment of the present invention;

FIGURE 3 is a block diagram illustrating rolling code operation that may be used with the present invention;

FIGURE 4 is a block diagram illustrating an automatically programmed remote control according to an embodiment of the present invention;

FIGURE 5 is a block diagram illustrating a remote sensor according to an embodiment of the present invention;

FIGURE 6 is a memory map illustrating activation signal sequencing according to an embodiment of the present invention; and

FIGURES 7-9 are flow charts illustrating operation of an automatically programmable remote control according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

A remotely controlled system, shown generally by 20, controls access to a garage, shown generally by 22. Garage 22 includes garage door 24 which can be opened and closed by garage door opener 26. Garage door opener 26 includes drive 28 for moving garage door 24, lamp 30 which turns on when garage door opener 26 is activated, and receiver 32 receiving radio frequency activation signal 34 for activating garage door opener 26. Garage door opener 26 receives electrical power through power cable 36 plugged into outlet 38 on the ceiling of garage 22.

Vehicle 40 includes programmable remote control 42 which generates a sequence of activation signals, shown generally by 44. Each activation signal in sequence of activation signals 44 has characteristics defined by one of a plurality of possible activation schemes. One of these schemes corresponds with activation signal 34 operating garage door opener 26. Selecting the proper activation signal 34 from sequence of activation signals 44 is based on sensing activation of garage door opener 26. A wide variety of sensing techniques are possible.

Remote sensor 46 may be placed within garage 22 to detect activation of garage door opener 26. For example, remote sensor 46 may respond to light from garage door opener lamp 30. Remote sensor 46 may also respond to vibration, including sound, produced by garage door opener 26 when drive 28 is in operation. Remote sensor 46 may also be magnetically or mechanically attached to garage door 24 for detecting motion and/or position of garage door 24. This may be accomplished, for example, by including in remote sensor 46 and accelerometer, inclinometer, or the like. Remote sensor 46 may also be mechanically or magnetically affixed to rail 50 upon which travels garage door 24. Remote sensor 46 may then include a velocimeter, accelerometer, microphone, or other vibration sensing transducer.

Remote sensor 46 may also operate together with appropriately positioned vehicle 40 for detecting activation of garage door opener 26. For

example, a light sensitive transducer in remote sensor 46 may be positioned facing garage door 24. Vehicle 40 is then positioned on the opposite side of garage door 24 with headlamps 48 turned on. Closing garage door 24 interrupts light from headlamps 48 from otherwise striking remote sensor 46. The change in light level detected by remote sensor 46 indicates the activation of garage door opener 26.

Remote sensor 46 transmits the activation state of garage door opener 26, or a change in the activation state, to programmable remote control 42. Programmable remote control 42 uses the signal received from remote sensor 46 to determine which activation signal in sequence of activation signals 44 corresponds to activation signal 34 operating garage door opener 26. Information defining activation signal 34 is stored in association with a control input for programmable controller 42.

As an alternative to, or in addition with, remote sensor 46, system 20 may use a sensor mounted on vehicle 40. This may be a sensor placed in vehicle 40 specifically for the purpose of detecting activation of garage door opener 26. However, system 20 may also utilize a sensor placed on vehicle 40 for another purpose. One example of such a sensor is a light sensor for controlling the operation of headlamps 48. Automatic headlamp systems switch between high beam and low beam or between low beam and daylight operation based on a detected ambient light level. If this light sensor is mounted near the front of vehicle 40, and vehicle 40 is parked near door 24, the presence or absence of light from headlamps 48 reflected from door 24 may be used to indicate whether door 24 is open or closed.

Another in-vehicle sensing mechanism that may be used for detecting appliance activation is associated with a collision avoidance system. Radar or ultrasound signals are transmitted from the front and/or rear of vehicle 48. Proximity of objects is detected when the transmitted signals reflect off the object and return to vehicle 40. Once again, by parking vehicle 40 near door 24, collision avoidance detection signals may be used to detect whether garage door 24 is opened or closed.

Vehicle 40 may also include one or more light sensors capable of distinguishing whether garage door opener lamp 30 is on or off. These light sensors are used in a variety of options including control of headlamps 48, automatic wiper control, automatic defrost or defog control, and the like. Parking vehicle 40 within garage 22 allows one or more of these light sensors to determine when garage door opener 26 is activated.

Still another in-vehicle sensor that may be used to implement system 20 is a microphone mounted within the passenger compartment of vehicle 40. Microphones are increasingly used for on-board telematics and voice-controlled options. Lowering a window or opening a door on vehicle 40 would allow these microphones to detect sound vibrations generated by garage door opener drive 28 when garage door opener 26 is activated.

The present invention has been generally descried with regard to a garage door opener. However, the present invention may be applied to controlling a wide variety of appliances such as other mechanical barriers, lighting systems, alarm systems, temperature control systems, and the like. Further, the remote control has been described as an in-vehicle remote control. The present invention also applies to remote controls that may be hand held, wall mounted, included in a key fob, and the like.

Referring now to Figure 2, a schematic diagram illustrating activation signal characteristics according to an embodiment of the present invention is shown. Information transmitted in an activation signal is typically represented as a binary data word, shown generally by 60. Data word 60 may include one or more fields, such as transmitter identifier 62, function indicator 64, code word 66, and the like. Transmitter identifier (TRANS ID) 62 uniquely identifies a remote control transmitter. Function indicator 64 indicates which of a plurality of functional buttons on the remote control transmitter were activated. Code word 66 helps to prevent misactivation and unauthorized access.

Several types of codes 66 are possible. One type of code is a fixed code, wherein each transmission from a given remote control transmitter contains the same code 66. In contrast, variable code schemes change the bit pattern of code 66 with each activation. The most common variable code scheme, known as rolling code, generates code 66 by encrypting a counter value. After each activation, the counter is incremented. The encryption technique is such that a sequence of encrypted counter values appears to be random numbers.

Data word 60 is converted to a baseband stream, shown generally by 70, which is an analog signal typically transitioning between a high voltage level and a low voltage level. Various baseband encoding or modulation schemes are possible, including polar signaling, on-off signaling, bipolar signaling, duobinary signaling, Manchester signaling, and the like. Baseband stream 70 has a baseband power spectral density, shown generally by 72, centered around a frequency of zero.

Baseband stream 70 is converted to a radio frequency signal through a modulation process shown generally by 80. Baseband stream 70 is used to modulate one or more characteristics of carrier 82 to produce a broadband signal, shown generally by 84. Modulation process 80, mathematically illustrated in Figure 2, implements a form of amplitude modulation commonly referred to as on-off keying. As will be recognized by one of ordinary skill in the art, many other modulation forms are possible, including frequency modulation, phase modulation, and the like. In the example shown, baseband stream 70 forms envelope 86 modulating carrier 82. As illustrated in broadband power spectral density 88, the effect in the frequency domain is to shift baseband power spectral density 72 to be centered around the carrier frequency, f, of carrier 82.

Referring now to Figure 3, a block diagram illustrating rolling code operation that may be used with the present invention is shown. Remotely controlled systems using rolling code require crypt key 100 in both the transmitter and the receiver for normal operation. In a well-designed rolling code scheme, crypt key 100 is never transmitted from the transmitter to the receiver. Typically, crypt key 100 is generated using key generation algorithm 102 based on transmitter

identifier 62 and a manufacturing (MFG) key 104. Crypt key 100 and transmitter identifier 62 are then stored in a particular transmitter. Counter 106 is also initialized in the transmitter. Each time an activation signal is sent, the transmitter uses encrypt algorithm 108 to generate rolling code 110 from counter 106 using crypt key 100. The transmitted activation signal includes rolling code 110 and transmitter identifier 62.

A rolling code receiver is trained to a compatible transmitter prior to operation. The receiver is placed into a learn mode. Upon reception of an activation signal, the receiver extracts transmitter identifier 62. The receiver then uses key generation algorithm 102 with manufacturing key 104 and received transmitter identifier 62 to generate crypt key 100 identical to the crypt key used by the transmitter. Newly generated crypt key 100 is used by decrypt algorithm 112 to decrypt rolling code 110, producing counter 114 equal to counter 106. The receiver then saves counter 114 and crypt key 100 associated with transmitter identifier 62. As is known in the encryption art, encrypt algorithm 108 and decrypt algorithm 112 may be the same algorithm.

In normal operation, when the receiver receives an activation signal, the receiver first extracts transmitter identifier 62 and compares transmitter identifier 62 with all learned transmitter identifiers. If no match is found, the receiver rejects the activation signal. If a match is found, the receiver retrieves crypt key 100 associated with received transmitter identifier 62 and decrypts rolling code 110 from the received activation signal to produce counter 114. If received counter 106 matches counter 114 associated with transmitter identifier 62, activation proceeds. Received counter 106 may also exceed stored counter 114 by a preset amount for successful activation.

Another rolling code scheme generates crypt key 100 based on manufacturing key 104 and a “seed” or random number. An existing transmitter sends this seed to an appliance receiver when the receiver is placed in learn mode. The transmitter typically has a special mode for transmitting the seed entered, for example, by pushing a particular combination of buttons. The receiver uses the

"seed" to generate crypt key 100. As will be recognized by one of ordinary skill in the art, the present invention applies to the use of a "seed" for generating a crypt key as well as to any other variable code scheme.

Referring now to Figure 4, a block diagram illustrating an automatically programmed remote control according to an embodiment of the present invention is shown. Appliance 120, such as garage door opener 26, is controlled by appliance receiver 122 based on receiving activation signal 34 through receiver antenna 124. Under the control of appliance receiver 122, appliance 120 modifies at least one parameter 126. Parameter 126 includes mechanical motion, mechanical position, light, temperature, sound, fluid level, humidity, voltage, current, power, resistance, inductance, capacitance, and the like.

Programmable remote control 42 includes sensor 128 for detecting one or more parameters 126 when sensor 128 is positioned proximate to appliance 120. Sensor 128 generates sensor signal 130 sent to control logic 132. Sensor signal 130 may represent a continuous variable or may be a binary variable indicating parameter 126 has crossed some threshold value. Sensor 128 may be hard wired to control logic 132. Sensor signal 130 may also travel along a bus interconnecting sensor 128 and control logic 132. Sensor signal 130 may also be transmitted using a radio link established between sensor 128 and control logic 132.

Programmable remote control 42 includes transmitter 134. An exemplary transmitter 134 includes variable oscillator 136, modulator 138, variable gain amplifier 140 and transmitter antenna 142. Transmitter 134 generates each activation signal in sequence of activation signals 44 by setting variable oscillator 136 to the carrier frequency. Modulator 138, represented here as a switch, modulates the carrier produced by variable oscillator 136 in response to data supplied by control logic 132. Variable gain amplifier 140 amplifies the modulated carrier to produce an activation signal transmitted from antenna 142.

When operating in a learn mode, control logic 132 generates sequence of activation signals 44 containing activation signal 34 implementing an activation

scheme recognized by appliance receiver 122. In response to at least one sensor signal 130, control logic 132 determines which activation signal 34 activated appliance 120. Control logic 132 stores data representing activation signal 34 associated with a particular user input channel. In operate mode, when control logic 132 receives a user activation input for this channel, control logic 132 retrieves the stored data and generates activation signal 34.

Programmable remote control 42 includes non-volatile memory, such as flash memory 144, that can be written to and read from by control logic 132. Flash memory 144 holds information used by control logic 132 for generating sequence of activation signals 44. Flash memory 144 also stores data indicating which activation signal 34 was successfully automatically programmed to activate appliance 120.

Programmable remote control 42 includes user interface 146 in communication with control logic 132. User interface 146 receives user input 148 and generates user output 150. For simple systems, user input 148 is typically provided by up to three pushbuttons. User output 150 may be provided by illuminating one or more display lamps. User input 148 and user output 150 may also be provided through a wide variety of control and display devices such as touch activated display screens, speech generators, tone generators, voice recognition systems, telematic systems, and the like.

Control logic 132 is preferably implemented with a microcontroller executing code held in a non-volatile memory such as flash memory 144. Control logic 132 may also be implemented using any combination of analog or digital discreet components, programmable logic, computers, and the like. In addition, elements of control logic 132, transmitter 134, flash memory 144 and/or user interface 146 may be implemented on a single integrated circuit chip for decreased cost in mass production.

Referring now to Figure 5, the block diagram illustrating a remote sensor according to an embodiment of the present invention is shown. Remote

sensor 128 is designed to measure current draw by appliance 120. Remote sensor 128 includes AC receptacle 160 and AC plug 162 allowing remote sensor 128 to be inserted between a power cord for appliance 120 and a power outlet such as power cable 36 and outlet 38, respectively, illustrated in Figure 1. Current sensor 164 senses current on a wire running between receptacle 160 and plug 162. Current senor 164 may be a low value resistor, current transformer, hall effect sensor, and the like. Buffer amplifier 166 amplifies the output of current sensor 164 for a peak detection circuit, shown generally by 168. The peak current level is sampled by an analog-to-digital converter in microcontroller 170.

Microcontroller 170 watches for significant changes in the peak level of sensed current. In the case of a garage door opener, a sharp increase in current corresponds with activating drive 28. By watching for a significant change in current draw, microcontroller 170 can ignore any low level current draw necessary to support electronics in garage door opener 26. When a change in current draw is detected, microcontroller 170 signals voltage controller oscillator 172 to transmit sensor signal 130 from antenna 174.

Programmable remote control 42 includes antenna 176 receiving radio frequency sensor signal 130. Receiver 178 detects radio frequency sensor signal 130 and signals control logic 132 that sensor 128 has detected a change in the activation state of appliance 120.

Sensor 128 may be battery powered. Alternatively transformer 180, inserted in line between receptacle 160 and plug 162, and power supply 182 provide regulated voltage for buffer amplifier 166, microcontroller 170 and voltage controlled oscillator 172.

Referring now to Figure 6, a memory map illustrating activation signal sequencing according to an embodiment of the present invention is shown. A memory map, shown generally by 190, represents the allocation of memory for data tables within programmable remote control 42. Preferably, this data is held in

non-volatile memory such as flash memory 144. Memory map 190 includes channel table 192, search table 194 and scheme table 196.

Channel table 192 includes a channel entry, one of which is indicated by 198, for each channel supported by programmable remote control 42. Typically, each channel corresponds to a user input. In the example illustrated in Figure 6, three channels are supported. Each channel entry 198 has two fields, scheme address 200 and fixed code 202. Scheme address 200 points to a field in scheme table 196 holding data describing characteristics of a particular activation scheme. Fixed code value 202 holds the programmed fixed code for a fixed code scheme. Fixed code value 202 may also hold function code 64 in fixed code modes. Fixed code value 202 may hold a function code 64 or may not be used at all in a channel programmed for a rolling scheme.

Search table 194 contains a sequence of scheme addresses 200 corresponding to the order of activation signals generated for sequence of activation signals 44. Addresses 200 may be arranged to generate a variety of sequences 44. For example, first sequence 204 may contain addresses 200 pointing to rolling code schemes and second sequence 206 may contain addresses 200 pointing to fixed code schemes. This will result in activation signals for all rolling code schemes being sent in sequence 44 prior to sending any activation signal for a fixed code scheme.

In another embodiment, at least some of addresses 200 are arranged based on popularity of activation schemes. In particular, activation schemes generating activation signals for appliances with greater market penetration are listed before schemes generating activation signals for less popular appliances. In this manner, the average latency before generating activation signal 34 for a given appliance is reduced.

Scheme table 196 holds characteristics and other information necessary for generating each activation signal in sequence of activation signals 44. Scheme table 196 includes a plurality of rolling code entries, one of which is indicated by 210, and a plurality of fixed code entries, one of which is indicated by

212. Each rolling code entry 210 includes transmitter identifier 62, counter 106, crypt key 100, carrier frequency 214, and subroutine address 226. Subroutine address 226 points to code executable by control logic 132 for generating an activation signal. Additional characteristics may be embedded within this code. Each fixed code entry 212 includes carrier frequency 214 and subroutine address 216.

Referring now to Figures 7-9, flow charts illustrating operation of an automatically programmable remote control according to an embodiment of the present invention are shown. As will be appreciated by one of ordinary skill in the art, the operations illustrated are not necessary sequential operations. Similarly, operations may be performed by software, hardware, or a combination of both. The present invention transcends any particular implementation and the aspects are shown in sequential flow chart form for ease of illustration.

Figure 7 illustrates a learn mode background routing. For a simple system with pushbuttons for input, a particular channel may be placed in learn mode by depressing the channel pushbutton for an extended period of time. The basic scheme shown in Figure 7 is to transmit each activation signal in sequence of activation signals 44 in rapid succession until sensor input indicates successful activation. Because there may be some lag between transmitting the successful activation signal and sensing appliance activation, the routine reverses the order of activation transmission. Enough delay is inserted between each activation signal transmitted a second time to detect another activation before the next transmission. This second pass through sequence of activation signals 44 is referred to as sense mode.

The amount of time required to transmit an entire sequence of activation signals 44 depends on the number and types of activation signals transmitted. As an example, consider a family of appliances which may be activated using one of 25 different schemes, ten of which are rolling code schemes and fifteen of which are fixed code schemes. Assume further that each fixed code scheme uses a ten bit fixed code, resulting in 15,360 different fixed code activation signals. For

simplicity, each fixed code transmission may be considered a separate activation scheme. Further, assume that each activation signal requires 50 msec to transmit and a further 50 msec in between each scheme transmission. Using these assumptions, all possible schemes can be transmitted within 26 minutes.

If most appliances are activated by either one of a rolling code type or one of only a few fixed code types, the average time until transmission of a successful activation signal can be decreased by transmitting activation signals corresponding to these types first.

With specific reference now to Figure 7, a pointer is set to the first scheme, as in block 220. A variable pointer is set to the first address 200 in search table 194 (START). A check is made to determine if any schemes remain, as in block 222. The pointer value is compared to the last address 200 in search table 194 (LAST). If any schemes remain, characteristics corresponding to the present scheme are retrieved, as in block 224. This may be accomplished by using the pointer address to extract characteristics from scheme table 196.

A check is made to determine if the present scheme is fixed, as in block 226. This may be accomplished based on the pointer value, based on information in scheme table 196, or the like. If not, a rolling code data word is formed, as in block 228. For example, crypt key 100 may be used to generate a rolling code value from counter 106. The rolling code value and transmitter identifier 162 are concatenated to form the data word. The data word is transmitted, as in block 230. A check is made to determine if the system is in sense mode, as in block 232. Sense mode is entered after receiving a sensor signal indicating the first successful appliance activation. If not in sense mode, flow continues at block 234. If in sense mode, a delay is introduced, as in block 236. This delay must be sufficient to allow the appliance to respond. In the example described, a delay of four seconds is used. Flow then continues with block 234.

Returning to now to block 226, if a fixed code activation signal is to be transmitted, the fixed code is initialized, as in block 240. A loop is then entered

for transmitting an activation signal for each fixed code value or scheme. A fixed code data word is formed, as in block 242. The fixed code value and any other necessary information such as, for example, transmitter identifier or function code are concatenated to form the data word. The data word is transmitted, as in block 244. A check is made to determine if the system is operating in sense mode, as in block 246. If so, a delay is introduced, as in block 248, and the fixed code is decremented, as in block 250. If not, the fixed code is incremented, as in block 252. A check is made to determine if an activation signal for each fixed code has been generated, as in block 254. If not, the fixed code loop is repeated. If so, flow continues at block 234.

In block 234, a check is made to determine if the system is in sense mode. If so, the scheme pointer is decreased, as in block 256. If not, the scheme pointer is advanced, as in block 258. A check is again made to determine if any schemes remain, as in block 222.

Returning again to block 222, if no schemes remain, a delay is introduced and the pointer is decreased to point to the last scheme, as in block 260. A check is made to determine if the system is in sense mode, as in block 262. If so, characteristics of the next scheme are loaded and activation signals are transmitted in reverse order. If not, programming is completed. A check is made to determine if success was indicated, as in block 264. If not, the user is notified of failure, as in block 266. If successful, the user is so notified, as in block 268. User notification of failure or success may be accomplished by flashing different patterns in one or more indicator lamps.

The search technique illustrated in Figure 7, namely rapidly searching up through a sequence then, after receiving a sensor signal, reversing the order and slowly searching down through the sequence, is one of many search techniques that can be used to identify the proper activation scheme. For example, a single slow search may be used. Another technique is to rapidly search up through the sequence the, after receiving a sensor signal, starting at some point within the sequence already transmitted and searching out in both directions. The point chosen may be

based on knowledge about expected delays between transmitting the correct activation signal and receiving the resulting sensor signal.

Referring now to Figure 8, a sensor routine for use in learn mode is illustrated. This routine may be implemented, for example, as an interrupt service routine triggered by receiving sensor signal 130. Sensor input is received, as in block 280. A check is made to determine if the input is valid, as in 282. This check may include comparison to a previous value, compensation for noise, switch debouncing, and the like. If the input is not valid, the routine is ended. If the input is valid, a check is made to determine if the current pass is the first pass through the routine, as in block 284. If so, the mode is set to sense mode, as in block 286. A delay may also be introduced, as in block 288. This delay allows the effect of appliance activation to settle out. For example, if the appliance is a garage door opener, the delay may be sufficient to permit the garage door to fully open or close.

Returning again to block 284, if the pass check indicates a second pass through the routine, parameters are stored, as in block 290. The current pointer value is stored as scheme address and, if a fixed code activation signal was sent, the fixed code is saved as fixed code 202 in the appropriate locations in channel table 192. The scheme and fix code are set to terminate, as in block 292. The pointer is set to the last value and, if necessary, the fixed code is set to the last possible fixed code value. This results in terminating the background loop illustrated in Figure 7 upon return from the interrupt service routine. A flag indicating success is set, as in block 294.

Referring now to Figure 9, operate mode is illustrated. User input is received, as in block 300. If pushbuttons are used, a short depression of a particular pushbutton indicates operate mode for the channel corresponding to the asserted pushbutton. Stored data for that channel is retrieved, as in block 302. This is accomplished by loading scheme address 200 and fixed code 202, if necessary, from the appropriate entry in channel table 192. The retrieved scheme address 200 is then used to load characteristics from scheme table 196. An activation signal is transmitted based on the retrieved data, as in block 304.

While embodiments of the invention have been illustrated and described, it is not intended that these embodiments illustrate and describe all possible forms of the invention. Rather, the words used in the specification are words of description rather than limitation, and it is understood that various changes may be made without departing from the spirit and scope of the invention.